

U.S. PATENT APPLICATION

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Invention: COATED ARTICLE WITH TIN OXIDE, SILICON NITRIDE AND/OR ZINC
OXIDE UNDER IR REFLECTING LAYER AND CORRESPONDING
METHOD

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SPECIFICATION

TITLE OF THE INVENTION

COATED ARTICLE WITH TIN OXIDE, SILICON NITRIDE AND/OR ZINC OXIDE UNDER IR REFLECTING LAYER AND CORRESPONDING METHOD

[0001] This application is a continuation-in-part (CIP) of U.S. Serial No. 10/645,838, filed August 22, 2003, the entire disclosure of which is hereby incorporated herein by reference.

[0002] This invention relates to a coated article including a layer comprising zinc oxide and a layer comprising silicon nitride under an infrared (IR) reflecting layer. In certain example embodiments, the coated article may be heat treated (e.g., thermally tempered, heat bent and/or heat strengthened). Coated articles herein may be used in the context of insulating glass (IG) window units, or in other suitable applications such as monolithic window applications, laminated windows, and the like.

BACKGROUND OF THE INVENTION

[0003] Coated articles are known in the art for use in window applications such as insulating glass (IG) window units, vehicle windows, monolithic windows, and/or the like. It is known that in certain instances, it is desirable to heat treat (e.g., thermally tempered, heat bent and/or heat strengthened) such coated articles for purposes of tempering, bending, or the like.

[0004] In certain example instances, designers of coated articles often strive for a combination of high visible transmission, substantially neutral color, low emissivity (or emittance), and low sheet resistance (R_s). High visible transmission and substantially neutral color may permit coated articles to be used in applications where these characteristics are desired such as in architectural or vehicle window applications, whereas low-emissivity (low-E) and low sheet resistance characteristics permit such coated articles to block significant amounts of IR radiation so as to reduce for example undesirable heating of vehicle or building interiors. In certain example instances, low U-values are also desired.

[0005] However, heat treatment of coated articles typically requires use of temperature(s) of at least 580 degrees C, more preferably of at least about 600 degrees C and still more preferably of at least 620 degrees C. The use of such high temperatures (e.g., for 5-10 minutes or more) often causes coatings to break down and/or causes one or more of the aforesaid desirable characteristics to significantly deteriorate in an undesirable manner. For example, thermal tempering of certain coated articles may cause color and/or visible transmission to shift to an undesirable value(s) that may be aesthetically and/or functionally displeasing.

[0006] In view of the above, it will be apparent to those skilled in the art that there exists a need for coated articles which are capable of providing high visible transmission, substantially neutral color, low emissivity (or emittance), and/or low sheet resistance (R_s). In certain example embodiments, it may be desired that one or all of these characteristics can be achieved even after the coated article has been heat treated.

BRIEF SUMMARY OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0007] In certain example embodiments of this invention, respective layers comprising silicon nitride and zinc oxide are used as a barrier below an infrared (IR) reflecting layer. The IR reflecting layer may be of or include silver or the like. In certain example instances, a layer stack comprising $\text{SnO}_2/\text{Si}_x\text{N}_y/\text{ZnO}_x$ is provided immediately under a silver inclusive IR reflecting layer in a low-E coating. It has been found that the use of such layers under an IR reflecting layer surprisingly result in improved thermal stability upon heat treatment, more neutral and/or desirable coloration, lower sheet resistance (R_s), and/or lower emissivity.

[0008] In certain example embodiments of this invention, a layer comprising zinc oxide may be provided over a contact layer that is in contact with an IR reflecting layer. Again, it has been found that the use of such a zinc oxide inclusive layer results in improved thermal stability upon heat treatment, more neutral and/or desirable coloration, lower sheet resistance (R_s), and/or lower emissivity.

[0009] In certain example embodiments of this invention, there is provided a coated article comprising the following layers from the glass substrate outwardly:

glass/TiO_x/SnO₂/Si_xN_y/ZnO/Ag/NiCrO_x/SnO₂/Si_xN_y. Optionally, a layer comprising zinc oxide may be provided between the NiCrO_x layer and the upper tin oxide layer in certain example instances. Other layers may be provided in certain instances, and it is possible that other materials may be used for certain layers. Surprisingly, it has been found that the provision of the barrier layer sequence below the IR reflecting layer (optionally combined with the zinc oxide over the IR reflective layer) provides for unexpected results. In particular, the resulting coated article upon heat treatment (HT) unexpectedly has, for example, one or more of: improved thermal stability, more neutral or desirable coloration, lower sheet resistance (R_s), and lower emissivity (e.g., hemispherical emissivity). These surprisingly results are highly advantageous since lower emissivity, lower sheet resistance, desirable coloration and/or thermal stability are typically desired features in coated articles.

[0010] In certain example embodiments, a layer comprising tin oxide is provided between a layer comprising titanium oxide and a layer comprising silicon nitride. Surprisingly, it has been found that the provision of such a tin oxide inclusive layer between layers comprising silicon nitride and titanium oxide can significantly improve durability of the resulting coated article, especially after heat treatment (HT). The overall adhesion in the coating improves due to this layer comprising tin oxide. With respect to durability, the reason for the remarkable improvement in durability is not clear. However, it is believed that it may be related to an interfacial adhesive problem between silicon nitride and titanium oxide. Undesirable stresses at this interface can be removed by inserting a layer of or including tin oxide between the titanium oxide inclusive layer and the silicon nitride inclusive layer, thereby allowing durability to be significantly improved.

[0011] In certain example embodiments of this invention, this layer stack portion may be used in the context of a single silver layer stack, although this invention is not so limited.

[0012] In certain example embodiments, there is provided a coated article comprising a coating supported by a glass substrate, the coating comprising: a first dielectric layer on the glass substrate; a first layer comprising tin oxide which further includes nitrogen, located over the first dielectric layer; a layer comprising silicon

nitride located over and contacting the first layer comprising tin oxide; a first layer comprising zinc oxide located over and contacting the layer comprising silicon nitride; an infrared (IR) reflecting layer comprising silver located over and contacting the first layer comprising zinc oxide; a contact layer located over and contacting the IR reflecting layer; a second layer comprising zinc oxide located over and contacting the contact layer; and another dielectric layer located over the second layer comprising zinc oxide. The coated article may or may not be heat treated in certain instances.

[0013] In other example embodiments of this invention, there is provided a coated article comprising a coating supported by a glass substrate, the coating comprising: a first dielectric layer on the glass substrate; a layer comprising tin oxide located over at least the first dielectric layer; a layer comprising silicon nitride located over and contacting the layer comprising tin oxide; a layer comprising zinc oxide located over and contacting the layer comprising silicon nitride; an infrared (IR) reflecting layer located over and contacting the layer comprising zinc oxide; a contact layer located over and contacting the IR reflecting layer; and at least another dielectric layer located over the contact layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIGURE 1 is a cross sectional view of a coated article according to an example embodiment of this invention.

[0015] FIGURE 2 is a cross sectional view of a coated article according to another example embodiment of this invention.

DETAILED DESCRIPTION OF EXAMPLES OF THE INVENTION

[0016] Coated articles herein may be used in applications such as monolithic windows, IG window units, vehicle windows, and/or any other suitable application that includes single or multiple glass substrates.

[0017] In certain example embodiments of this invention, there is provided a coated article comprising the following layers from the glass substrate outwardly:

glass/TiO_x/SnO₂/Si_xN_y/ZnO/Ag/NiCrO_x/ZnO/SnO₂/Si_xN_y. In other example embodiments of this invention, there is provided a coated article comprising the layers glass/TiO_x/SnO₂/Si_xN_y/ZnO/Ag/NiCrO_x/SnO₂/Si_xN_y. Other layers and/or other materials may also be utilized in certain example embodiments of this invention. For example, while the aforesaid coating is a single silver stack, this invention is not so limited.

[0018] Unexpectedly, it has been found that the provision of the barrier comprising the silicon nitride and zinc oxide inclusive layers below the silver layer provide for superior results (compared to if the silicon nitride for example was not provided). In particular, by using a sequence of tin oxide/silicon nitride/zinc oxide immediately below the IR reflecting silver inclusive layer, the resulting coated article when heat treated unexpectedly has, for example: improved thermal stability, more neutral and/or desirable coloration, higher visible transmission, lower sheet resistance (R_s), and lower emissivity (e.g., hemispherical emissivity). These surprisingly results associated with the use of, for example, the combination layer stack portion of glass . . . SnO₂/Si_xN_y/ZnO/Ag . . . are highly advantageous and represent a significant improvement in the art, since lower emissivity, lower sheet resistance, higher visible transmission, desirable coloration and/or thermal stability are desired features in coated articles.

[0019] Additionally, in certain example embodiments of this invention, it has also been found that the provision of the zinc oxide inclusive layer directly over the nickel chrome oxide inclusive layer above the silver infrared (IR) reflecting layer provides for unexpected results. In particular, by using zinc oxide in this layer (as opposed to solely tin oxide for example), the resulting coated article when heat treated unexpectedly has, for example: improved thermal stability, more neutral and/or desirable coloration, lower sheet resistance (R_s), and lower emissivity (e.g., hemispherical emissivity). These surprisingly results associated with the use of the combination layer stack portion of glass . . . ZnO/Ag/NiCrO_x/ZnO . . . are highly advantageous and represent a significant improvement in the art, since lower emissivity, lower sheet resistance, desirable coloration and/or thermal stability are desired features in coated articles.

[0020] The terms "heat treatment" and "heat treating" as used herein mean heating the article to a temperature sufficient to achieve thermal tempering, bending, and/or heat strengthening of the glass inclusive article. This definition includes, for example, heating a coated article in an oven or furnace at a temperature of least about 580 degrees C, more preferably at least about 600 degrees C, for a sufficient period to allow tempering, bending, and/or heat strengthening. In certain instances, the HT may be for at least about 4 or 5 minutes.

[0021] Fig. 1 is a cross sectional view of a coated article (heat treated, or non-heat treated) according to an example embodiment of this invention. The coated article includes glass substrate 1 (e.g., clear, green, bronze, or blue-green glass substrate from about 1.0 to 10.0 mm thick, more preferably from about 1.0 mm to 6.0 mm thick), and a multi-layer coating (or layer system) provided on the substrate either directly or indirectly. As shown in Fig. 1, the coating comprises dielectric layer 3 of a material such as titanium oxide, dielectric layer 4 of or including a metal oxide such as tin oxide, silicon nitride inclusive layer 5, zinc oxide inclusive layer 7, IR reflecting layer 9 including or of silver, gold, or the like, upper contact layer 11 of or including an oxide of nickel chrome (e.g., NiCrO_x), zinc oxide inclusive layer 13, dielectric layer 14 comprising a metal oxide such as tin oxide, and dielectric layer 15 of or including a material such as silicon nitride which may in certain example instances be a protective overcoat. Other layers and/or materials may also be provided in certain example embodiments of this invention, and it is also possible that certain layers may be removed or split in certain example instances.

[0022] In monolithic instances, the coated article includes only one glass substrate 1 as illustrated in Fig. 1. However, monolithic coated articles herein may be used in devices such as IG window units for example. Typically, an IG window unit may include two spaced apart substrates. Example IG window units are illustrated and described, for example, in U.S. Patent Nos. 5,770,321, 5,800,933, 6,524,714, 6,541,084 and US 2003/0150711, the disclosures of which are all hereby incorporated herein by reference. An example IG window unit may include, for example, the coated glass substrate 1 shown in Fig. 1 coupled to another glass substrate via spacer(s), sealant(s) or the like with a gap being defined therebetween. This gap

between the substrates in IG unit embodiments may in certain instances be filled with a gas such as argon (Ar). An example IG unit may comprise a pair of spaced apart clear glass substrates each about 4 mm thick one of which is coated with a coating herein in certain example instances, where the gap between the substrates may be from about 5 to 30 mm thick, more preferably from about 10 to 20 mm, and most preferably about 16 mm. In certain example instances, the coating may be provided on the side of the glass substrate 1 facing the gap.

[0023] In certain example IG unit embodiments of this invention, the coating is designed such that the resulting IG unit (e.g., with, for reference purposes, a pair of 4 mm clear glass substrates spaced apart by 16 mm with Ar gas in the gap) has a U-value of no greater than $1.25 \text{ W}/(\text{m}^2\text{K})$, more preferably no greater than $1.20 \text{ W}/(\text{m}^2\text{K})$, even more preferably no greater than $1.15 \text{ W}/(\text{m}^2\text{K})$, and most preferably no greater than $1.10 \text{ W}/(\text{m}^2\text{K})$.

[0024] The bottom dielectric layer 3 may be of or include titanium oxide in certain example embodiments of this invention. The titanium oxide of layer 3 may in certain example instances be represented by TiO_x , where x is from 1.5 to 2.5, most preferably about 2.0. The titanium oxide may be deposited via sputtering or the like in different embodiments. In certain example instances, dielectric layer 3 may have an index of refraction (n), at 550 nm, of at least 2.0, more preferably of at least 2.1, and possibly from about 2.3 to 2.6 when the layer is of titanium oxide. In certain embodiments of this invention, the thickness of titanium oxide inclusive layer 3 is controlled so as to allow a* and/or b* color values (e.g., transmissive, film side reflective, and/or glass side reflective) to be fairly neutral (i.e., close to zero) and/or desirable. Other materials may be used in addition to or instead of titanium oxide in certain example instances.

[0025] Dielectric layer 4 may be of or include a metal oxide such as tin oxide in certain example embodiments of this invention. The tin oxide layer may be of SnO_2 or any other suitable stoichiometry in certain instances. Surprisingly, it has been found that the provision of such a tin oxide inclusive layer 4 (e.g., SnO_2 or $\text{SnO}_2\text{:N}$) between layers comprising silicon nitride 5 and titanium oxide 3 can significantly improve durability of the resulting coated article, especially after heat

treatment (HT). The overall adhesion in the coating improves due to this layer 4 comprising tin oxide. With respect to durability, the reason for the remarkable improvement in durability is not clear. However, it is believed that it may be related to an interfacial adhesive problem between silicon nitride 5 and titanium oxide 3. Undesirable stresses at this interface can be removed by inserting a layer of or including tin oxide 4 between the titanium oxide inclusive layer 3 and the silicon nitride inclusive layer 5, thereby allowing durability to be significantly improved.

[0026] Tin oxide layer 4 may or may not be doped with nitrogen (N) (e.g., from about 0-50 atomic %, more preferably from about 1-50 atomic %, even more preferably from about 2-25 atomic %, and most preferably from about 3-20 atomic %) so as to form $\text{SnO}_x\text{:N}$ where x is from about 1.5 to 2.5, more preferably from about 1.8 to 2.2, and may be 2.0 for example. While it is possible that the nitrogen in the tin oxide layer 4 may form an oxynitride in certain example instances, it is believed that the nitrogen therein more likely is trapped in the layer. It is believed that the inclusion of nitrogen in the tin oxide layer 4 may help keep the target clean and/or reduce the effect of internal stresses in the layer so as to allow better heat treatability in certain example embodiments of this invention.

[0027] Dielectric layer 5 may be of or include silicon nitride in certain embodiments of this invention. It has been found that silicon nitride layer 5 may, among other things, improve heat-treatability of the coated articles, e.g., such as thermal tempering or the like. The silicon nitride of layer 5 may be of the stoichiometric type (Si_3N_4) type, or alternatively non-stoichiometric in different embodiments of this invention. For example, Si-rich silicon nitride combined with zinc oxide inclusive layer 7 under a silver layer 9 may permit the silver to be deposited (e.g., via sputtering or the like) in a manner which causes its sheet resistance to be lessened compared to if certain other material(s) were under the silver. Moreover, the presence of free Si in a Si-rich silicon nitride inclusive layer 5 may allow certain atoms such as sodium (Na) which migrate outwardly from the glass 1 during HT to be more efficiently stopped by the Si-rich silicon nitride inclusive layer before they can reach the silver and damage the same. Thus, it is believed that the oxidation caused by heat treatment allows visible transmission to increase, and

that the Si-rich Si_xN_y in layer 5 can reduce the amount of damage done to the silver layer(s) during HT in certain example embodiments of this invention thereby allowing sheet resistance (R_s) to decrease in a satisfactory manner.

[0028] In certain example embodiments, when Si-rich silicon nitride is used in layer 5, the Si-rich silicon nitride layer 5 may be characterized by Si_xN_y layer(s), where x/y may be from 0.76 to 1.5, more preferably from 0.8 to 1.4, still more preferably from 0.85 to 1.2. Moreover, in certain example embodiments, before and/or after HT the Si-rich Si_xN_y layer(s) 5 may have an index of refraction "n" of at least 2.05, more preferably of at least 2.07, sometimes at least 2.10, and even at least 2.15 in certain instances (e.g., 632 nm) (note: stoichiometric Si_3N_4 which may also be used has an index "n" of 2.04 or less). Also, the Si-rich Si_xN_y layer in certain example embodiments may have an extinction coefficient "k" of at least 0.001, more preferably of at least 0.003 (note: stoichiometric Si_3N_4 has an extinction coefficient "k" of effectively 0).

[0029] The silicon nitride layer 5 may be doped with other materials such as stainless steel or aluminum in certain example embodiments of this invention. For example, the silicon nitride layer 5 may include from about 0-15% aluminum, more preferably from about 1 to 10% aluminum, in certain example embodiments of this invention. The silicon nitride may be deposited by sputtering a target of Si or SiAl in certain embodiments of this invention.

[0030] Infrared (IR) reflecting layer 9 is preferably substantially or entirely metallic and/or conductive, and may comprise or consist essentially of silver (Ag), gold, or any other suitable IR reflecting material. IR reflecting layer 9 help allow the coating to have low-E and/or good solar control characteristics. The IR reflecting layer may, however, be slightly oxidized in certain embodiments of this invention.

[0031] The upper contact layer 11 may be of or include nickel (Ni) oxide, chromium/chrome (Cr) oxide, or a nickel alloy oxide such as nickel chrome oxide (NiCrO_x), or other suitable material(s), in certain example embodiments of this invention. The use of, for example, NiCrO_x in this layer allows durability to be improved. The NiCrO_x layer 11 may be fully oxidized in certain embodiments of this invention (i.e., fully stoichiometric), or alternatively may only be partially oxidized.

In certain instances, the NiCrO_x layer 11 may be at least about 50% oxidized. Contact layer 11 (e.g., of or including an oxide of Ni and/or Cr) may or may not be oxidation graded in different embodiments of this invention. Oxidation grading means that the degree of oxidation in the layer changes throughout the thickness of the layer so that for example a contact layer may be graded so as to be less oxidized at the contact interface with the immediately adjacent IR reflecting layer than at a portion of the contact layer(s) further or more/most distant from the immediately adjacent IR reflecting layer. Descriptions of various types of oxidation graded contact layers are set forth in U.S. Patent No. 6,576,349, the disclosure of which is hereby incorporated herein by reference. Contact layer 11 (e.g., of or including an oxide of Ni and/or Cr) may or may not be continuous in different embodiments of this invention across the entire IR reflecting layer.

[0032] Layer 13 and lower contact layer 7 in certain embodiments of this invention are of or include zinc oxide (e.g., ZnO). The zinc oxide of layer(s) 7 and/or 13 may contain other materials as well such as Al (e.g., to form ZnAlO_x). For example, in certain example embodiments of this invention, one or both of zinc oxide layers 7 and 13 may be doped with from about 1 to 10% Al, more preferably from about 1 to 5% Al, and most preferably about 2 to 4% Al. The use of zinc oxide under the silver 9 allows for an excellent quality of silver to be achieved.

[0033] Surprisingly, it has been found that the provision of zinc oxide inclusive layer 13 directly over the nickel chrome oxide contact layer 11 above the silver infrared (IR) reflecting layer 9 provides for unexpected results. In particular, by using zinc oxide in this layer 13 (as opposed to solely tin oxide for example), the resulting coated article when heat treated unexpectedly has, for example: improved thermal stability, more neutral and/or desirable coloration, lower sheet resistance (R_s), and lower emissivity (e.g., hemispherical emissivity). These surprisingly results associated with the use of the combination layer stack portion of glass $\text{ZnO}/\text{Ag}/\text{NiCrO}_x/\text{ZnO}$ are highly advantageous and represent a significant improvement in the art, since lower emissivity, lower sheet resistance, desirable coloration and/or thermal stability are desired features in coated articles. Thus, in certain example embodiments of this invention, coated articles may be taken to higher

temperatures during heat treatment without suffering undesirable color shifts, significant transmission drops, and/or increases in sheet resistance (this is advantageous in view of the fact that many different types of furnaces may be used to heat treat coated articles, and different furnaces typically have different characteristics such as temperature). Additionally, it has also been found that by using zinc oxide in this layer 13 (as opposed to solely tin oxide for example), the resulting coated article is unexpectedly more durable with respect to temperature/humidity testing. Further details regarding the use of zinc oxide layer 13 are discussed in U.S. Serial No. 10/787,823, filed February 27, 2004, the disclosure of which is hereby incorporated herein by reference.

[0034] While the reasons for these unexpected results associated with the use of zinc oxide in layer 13 and/or the tin oxide/silicon nitride/zinc oxide layers 4/5/7 are not entirely clear, it is believed that the use one or more of these materials for some reason causes the silver of IR reflecting layer 9 to be more dense and have a more preferred orientation before and/or after heat treatment (HT). It is very surprising that this is the case, especially since a contact layer 11 (e.g., NiCrO_x) is provided between the zinc oxide layer 13 and the silver layer 9 in certain example instances. Because the zinc oxide in layer 13 causes the silver in layer 9 to be more dense and/or have a more preferred orientation, the silver and thus the overall coating is better able to withstand heat treatment at high temperatures so that a heat treated coated article with lower sheet resistance and emissivity is obtainable. Moreover, because the zinc oxide in layer 13 causes the silver in layer 9 to be more dense and/or have a more preferred orientation, it is believed that color shifting during heat treatment can be controlled in a desirable manner.

[0035] Dielectric layer 14 may be of or include tin oxide in certain example embodiments of this invention. Optionally, this layer may be omitted in certain embodiments of this invention.

[0036] Dielectric layer 15, which may be an overcoat in certain example instances, may be of or include silicon nitride (e.g., Si_3N_4) or any other suitable material in certain example embodiments of this invention. Optionally, other layers may be provided above layer 15. Layer 15 is provided for durability purposes, and to

protect the underlying layers during heat treatment and/or environmental use. In certain example embodiments, layer 15 may have an index of refraction (n) of from about 1.9 to 2.2, more preferably from about 1.95 to 2.05.

[0037] Other layer(s) below or above the illustrated coating may also be provided. Thus, while the layer system or coating is "on" or "supported by" substrate 1 (directly or indirectly), other layer(s) may be provided therebetween. Thus, for example, the coating of Fig. 1 (or Fig. 2) may be considered "on" and "supported by" the substrate 1 even if other layer(s) are provided between layer 3 and substrate 1. Moreover, certain layers of the illustrated coating may be removed in certain embodiments, while others may be added between the various layers or the various layer(s) may be split with other layer(s) added between the split sections in other embodiments of this invention without departing from the overall spirit of certain embodiments of this invention.

[0038] While various thicknesses may be used in different embodiments of this invention, example thicknesses and materials for the respective layers on the glass substrate 1 in the Fig. 1 embodiment are as follows, from the glass substrate outwardly:

Table 1 (Example Materials/Thicknesses; Fig. 1 Embodiment)

Layer	Preferred Range (Å)	More Preferred (Å)	Example (Å)
TiO _x (layer 3)	30-400 Å	100-150 Å	150 Å
SnO ₂ :N (layer 4)	10-300 Å	15-100 Å	30 Å
Si _x N _y (layer 5)	40-300 Å	50-200 Å	100 Å
ZnO _x (layer 7)	10-300 Å	30-100 Å	50 Å
Ag (layer 9)	50-250 Å	80-150 Å	120 Å
NiCrO _x (layer 11)	10-80 Å	20-70 Å	45 Å
ZnO (layer 13)	40-400 Å	100-150 Å	129 Å
SnO ₂ (layer 14)	10-350 Å	15-300 Å	200 Å
Si ₃ N ₄ (layer 15)	50-750 Å	100-350 Å	250 Å

[0039] In certain example embodiments of this invention, coated articles herein may have the following low-E (low emissivity) and/or solar characteristics set

forth in Table 2 when measured monolithically (before any possible HT) (e.g., 4 mm thick clear glass substrate).

Table 2: Low-E/Solar Characteristics (Monolithic; pre-HT)

Characteristic	General	More Preferred	Most Preferred
R_s (ohms/sq.):	≤ 10.0	≤ 6.5	≤ 6.0
E_h :	≤ 0.14	≤ 0.10	≤ 0.08
T_{vis} (%):	≥ 70	≥ 80	≥ 83

[0040] In certain example embodiments, coated articles herein may have the following characteristics, measured monolithically for example, after HT:

Table 3: Low-E/Solar Characteristics (Monolithic; post-HT)

Characteristic	General	More Preferred	Most Preferred
R_s (ohms/sq.):	≤ 8.0	≤ 5.0	≤ 4.3 (or ≤ 4.0)
E_h :	≤ 0.11	≤ 0.07	≤ 0.05
T_{vis} (%):	≥ 75	≥ 85	≥ 87

[0041] Moreover, coated articles including coatings according to certain example embodiments of this invention have the following optical characteristics (e.g., when the coating(s) is provided on a clear soda lime silica glass substrate 1 from 1 to 10 mm thick) (HT or non-HT). In Table 4, all parameters are measured monolithically, unless stated to the contrary such as with U-value which is measured post-HT and, for purposes of reference only and without limitation, in the context of an IG window unit with a pair of 4mm thick clear glass substrates spaced 16mm apart via a gap filled with Ar gas. In Table 4 below, R_fY is visible reflection from the side of the monolithic article on which coating is located (i.e., "f" means film side of monolithic article). As explained above, it is noted that U-value is measured in the context of an IG Unit, as is T_{vis-IG} (not monolithic like the rest of the data in Table 4). Likewise, Δa^* and Δb^* are measures of how much a^* and b^* , respectively, change due to heat treatment.

Table 4: Example Optical Characteristics (before and/or after HT)

Characteristic	General	More Preferred
T_{vis} (or TY)(Ill. C, 2 deg.):	$\geq 70\%$	$\geq 80\%$
a^*_t (Ill. C, 2°):	-2.5 to +1.0	-2.0 to 0.0

b^*_t (Ill. C, 2°):	-1.0 to +4.0	0.0 to 3.0
Δa^*_t :	≤ 1.0	≤ 0.7 (or ≤ 0.5)
Δb^*_t :	≤ 1.0	≤ 0.5
$R_f Y$ (Ill. C, 2 deg.):	1 to 7%	1 to 6%
a^*_f (Ill. C, 2°):	-6.0 to +7.0	-3.5 to +5.5
b^*_f (Ill. C, 2°):	-14.0 to +10.0	-10.0 to 0
T_{vis-IG} :	$\geq 70\%$	$\geq 78\%$
U-value (IG)(W/(m ² K)):	≤ 1.25	≤ 1.15 (or ≤ 1.10)

[0042] The value(s) Δa^* and Δb^* above, in view of their rather low values, illustrate thermal stability of these transmissive color values due to HT.

[0043] Fig. 2 is a cross sectional view of a coated article according to another example embodiment of this invention. The Fig. 2 embodiment is the same as the Fig. 1 embodiment, except that the upper zinc oxide layer is not present in the Fig. 2 embodiment.

EXAMPLE 1

[0044] The following example is provided for purposes of example only, and is not intended to be limiting. The following Example was made via sputtering so as to have approximately the layer stack set forth below, from the clear glass substrate (4 mm thick clear) outwardly.

Table 5: Layer Stack for Example

Layer
Glass Substrate
TiO_x
SnO₂:N
Si_xN_y
ZnAlO_x
Ag
NiCrO_x
ZnAlO_x
SnO₂
Si₃N₄

[0045] The process used in forming the coated article of the Example is set forth below. Below, the gas flows (argon (Ar), oxygen (O), and nitrogen (N)) are in units of sccm, and include both tuning gas and gas introduced through the main. The linespeed was about 4.0 m/min. The pressures are in units of mbar x 10⁻³. The silicon (Si) targets, and thus the silicon nitride layers, were doped with about 10% aluminum (Al), so as to be indicated by SiAl targets. The Zn targets in a similar manner were also doped with Al. Power is in units of kW, and Volts in V. Dual C-Mag targets were used for the titanium, silicon, and zinc targets, whereas planar targets were used for the tin, silver and nichrome targets.

Table 6: Sputter Processing Used in Example

Cathode	Target	Power	Ar	O	N	Pressure
C02	TiO	63	450	40	0	2.65
C04	Sn	6.7	125	240	75	3.91
C06	SiAl	37.5	350	0	420	3.21
C07	ZnAl	39.8	250	438	0	2.68
C09	Ag	4.3	250	0	0	1.74
C10	Ag	4.0	250	0	0	2.34
C11	NiCr (80/20)	12.2	200	88	0	2.34
C12	ZnAl	14.7	350	240	0	7.46
C14	Sn	13.0	125	350	75	1.54
C16	Sn	13.1	125	380	75	1.76
C25	SiAl	73.2	350	0	660	2.43
C26	SiAl	73.3	350	0	660	2.43

[0046] After being sputter deposited onto the glass substrate, an example sputtered in a manner similar to that set forth above had the following characteristics before being subjected to heat treatment, measured monolithically and in the center of the coated article:

Table 7: Characteristics (Monolithic – pre-HT)

Characteristic

Visible Trans. (T_{vis} or TY)(Ill. C 2 deg.): 84.1%

a*	-1.9
b*	2.6
Glass Side Reflectance (RY)(Ill C, 2 deg.):	6.5%
a*	0.9
b*	-10.4
Film Side Reflective (FY)(Ill. C, 2 deg.):	4.3
a*	2.2
b*	-9.3
R _s (ohms/square) (pre-HT):	5.8

[0047] After being heat treated at about 625 degrees C for about 10 minutes, the coated article had the following characteristics, measured monolithically and in the center of the coated article:

Table 8: Characteristics (Monolithic – post-HT)

Characteristic	
Visible Trans. (T _{vis} or TY)(Ill. C 2 deg.):	87.9%
a*	-2.0
b*	2.2
Glass Side Reflectance (RY)(Ill C, 2 deg.):	6.1%
a*	3.6
b*	-10.4
Film Side Reflective (FY)(Ill. C, 2 deg.):	4.9
a*	4.1
b*	-9.4
R _s (ohms/square) (post-HT):	3.8

[0048] It can be seen from the above that following heat treatment the coated article was characterized by substantially neutral transmissive a* and b* color values, high visible transmission, and low sheet resistance. This is highly advantageous, as these color values are typically viewed as aesthetically pleasing to those in the art. Thermal stability is evidenced by the fact that transmissive Δa^* and Δb^* values (i.e., how much a* and b* changed due to HT) were fairly low and important transmissive and film side reflective color values (a*, b*) were desirable following heat treatment.

Moreover, it can be seen that very high visible transmission and very low sheet resistance were achieved following heat treatment.

COMPARATIVE EXAMPLE

[0049] A Comparative Example (CE) had the following layer stack.

Table 9: Sputter Processing Used in CE

Cathode	Target	Power	Volts	Ar	O	N	Pressure
C66	TiO	33	355/341	350	42	0	1.85
C65	TiO	33	346/343	350	42	0	2.01
C59	SiAl	43	248	350	0	437	2.24
C53	ZnAl	21.5	220	350	255	0	2.05
C49	Ag	4	374/366	500	10	0	1.45
C48	NiCr	16	563	250	181	0	1.35
C46	Sn	27	247	250	480	100	1.57
C37	SiAl	87	327	350	0	598	2.51
C36	SiAl	87	327	350	0	598	1.96

[0050] For the Comparative Example (CE), it can be seen that zinc oxide layer 13 and tin oxide inclusive layer 4 were eliminated (compared to the Example above). Following heat treatment at about 625 degrees C for about 10 minutes, a comparison of certain characteristics is set forth below between the Comparative Example and the Example above of the Fig. 1 embodiment of this invention.

[0051] Table 10: Characteristics of Example and CE (Mono – post-HT)

Characteristic	Example	CE
Visible Trans. (T_{vis} or TY)(Ill. C 2 deg.):	87.9%	83.74%
a*	-2.0	-2.26
b*	2.2	-0.41
R_s (ohms/square) (post-HT):	3.8	4.5

[0052] It can be seen from the above that the Example had much better visible transmission (i.e., significantly higher) than the CE, and also had much better sheet

resistance (i.e., significantly lower) than the CE following HT. Thus, it can be seen that the presence of the zinc oxide inclusive layer 13 and/or tin oxide inclusive layer 4 provide for unexpectedly improved results in these respects according to certain example embodiments of this invention.

[0053] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.